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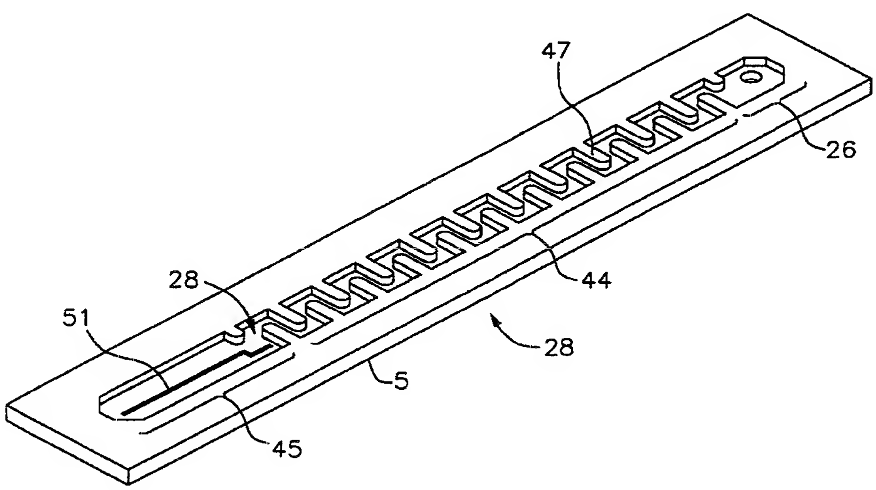
(54) Title: UNIBODY PRESSURE–COMPENSATING EMITTER



(57) Abstract

A unibody pressure–compensating emitter (24) is provided for use in a drip irrigation hose. The emitter comprises a top wall (5) and two side walls, and optionally front and back walls. The emitter (24) can further comprise a bottom wall, or the bottom side of the emitter can be enclosed by the wall of the hose. The walls of the emitter define a flow section (28) therebetween. The flow section (28) comprises an inlet section (26), an outlet section, a pressure–compensating section (45), preferably between the inlet section (26) and outlet sections, and at least one resistance element (47), preferably between the inlet section (26) and the pressure compensating section (45). At least one of the emitter walls is capable of deforming into the pressure–compensating section (45) with increased water pressure in the hose.

UNIBODY PRESSURE-COMPENSATING EMITTER

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority of U.S. Application Nos. 60/051,977 (filed July 9, 1997), 60/055,992 (filed August 28, 1997), and 60/074,399 (filed February 11, 1998), the disclosures of which are incorporated herein by reference.

FIELD OF THE INVENTION

This invention relates to pressure compensating emitters for use with drip irrigation hoses.

BACKGROUND OF THE INVENTION

Within a drip irrigation hose, water pressure varies due to changes in the slopes of the field. The water pressure also changes simply due to the internal resistance to flow inside the hose (line loss), i.e., the water pressure decreases as the water travels further along the hose. Because the water pressure changes, the flow rate of the water dripping out of the hose at any given outlet is generally different from the amount of water dripping from a different outlet. However, farmers generally prefer that every plant in the field get the same amount of water. Thus, it is desirable to provide within the hose emitters that "compensate" for the changes in internal hose pressure throughout the field.

When pressure-compensating emitters are used, the water pressure in the hose has less effect on the amount of water that ultimately drips out of the hose. Thus, the flowrate from any emitter along the length of the hose will tend to be more constant.

The drip flow rate of such a hose is proportional to the water pressure at the inlet to the emitters raised to the exponent x. In the absence of pressure compensation, the x-factor is one, i.e., the flow rate is a linear function of the pressure. In the ideal case of perfect pressure compensation, the x-factor is zero, i.e., the flow rate is independent of pressure. Thus, the x-factor is a measure of the degree of pressure compensation--the lower the x-factor, the greater the pressure compensation. Generally, a hose having an x-factor of about 0.5 is considered to be somewhat pressure-compensating. A hose having an x-factor of 0.1 is considered highly pressure-compensating.

Several prior art emitters have been designed to achieve a low x-factor. However, due to the complexity of these emitters, they can become expensive to manufacture. Thus, there is a need for an emitter design capable of achieving a low x-factor that is inexpensive to manufacture.

SUMMARY OF THE INVENTION

The present invention is directed to a unibody pressure-compensating emitter for use in a drip irrigation hose. The emitter comprises a top wall and two side walls, and optionally front and back walls. The emitter can further comprise a bottom wall, or the bottom side of the emitter can be enclosed by the wall of the hose. The walls of the emitter define a flow section therebetween. The flow section comprises an inlet section, an outlet section, a pressure-compensating section, preferably between the inlet and outlet sections, and at least one resistance element, preferably between the inlet section and the pressure-compensating section. At least one of the emitter walls is capable of deforming into the pressure-compensating section with increased water pressure in the hose. Preferably at least one wall, and more preferably all of the walls, of the emitter is made of a thermoplastic elastomer. The invention is also directed to a drip irrigation hose containing an emitter as described above, preferably a discrete emitter as described above.

DESCRIPTION OF THE DRAWINGS

These and other features and advantages of the present invention will be better understood by reference to the following detailed description when considered in conjunction with the accompanying drawings wherein:

FIG. 1 is a side cross-sectional view of a drip irrigation hose containing an emitter according to the invention.

FIG. 2 is a side cutaway view of a drip irrigation hose containing an emitter according to the invention.

FIG. 3A is top view of an emitter according to the invention.

FIG. 3B is a side cross-sectional view of the inlet section of the emitter of FIG. 3A.

FIG. 3C is a side cross-sectional view of the turbulent flow section of the emitter of FIG. 3A.

FIG. 3D is a side cross-sectional view of the pressure-compensation region of the emitter of FIG. 3A.

FIG. 3E is a side cross-sectional view of the outlet section of the emitter of FIG. 3A.

FIG. 4 is a side cutaway view of a drip irrigation hose containing an alternative embodiment of an emitter according to the invention.

FIG. 5 is a side cutaway view of a drip irrigation hose containing another alternative embodiment of an emitter according to the invention.

FIG. 6 is a top view of an emitter according to the invention with the flow section of the emitter shown in phantom.

FIG. 7 is a perspective view of an emitter according to the invention.

DETAILED DESCRIPTION

The present invention is directed to unibody pressure-compensating emitters for use in drip irrigation hoses. Each emitter 24 contains one or more walls capable of deforming when the water pressure inside the hose is increased.

FIG. 1 shows an emitter 24 within a drip irrigation hose 10. The drip irrigation hose 10 is made from an elongated strip of plastic film 12, which is typically 4 to 20 mil thick. Strip 12 is folded longitudinally to form overlapping inner and outer longitudinal margins 14 and 16, respectively. A longitudinal rib 20 seals margins 14 and 16. By virtue of the longitudinal fold in strip 12, the interior surface of strip 12 defines a relatively large water supply passage 23, which is connected to a source of water under pressure.

The emitter 24, which is a unibody emitter, is located within the hose 10 so that it is exposed to the water pressure in passage 23. As used herein, the term "unibody emitter" refers to a single-piece emitter that forms an inseparable assembly.

The emitter 24 has a top wall 5 and two side walls 6, and, in the case of a discrete emitter, a front wall 3 and a back wall 4, which, along with the wall of the hose 10, form at least one flow regulating channel 25 with an approximately rectangular cross-section. Preferably the top wall of the emitter is wider than the side walls are deep to permit better deformation of the top wall into the recess between the side walls. As shown in FIG. 2, each flow regulating channel 25 has an inlet section 26, which comprises one or more inlet openings through which water flows from the water supply passage 23, a flow section 28, and an outlet section 30 from which the water flows to the exterior of the hose 10. Of course, the emitter could alternatively have four walls with an outlet corresponding to an outlet, such as a hole or slit, in the hose.

The flow section 28 provides a flow passage between the inlet section 26 and outlet section 30 and contains at least one pressure-compensating section 45. A pressure-compensating section 45 is a flow passage that adjusts the flow rate of water passing through it in response to the water pressure in the large water supply passage 23 by deformation of one or more walls. The pressure-compensating section 45 can have any configuration capable of achieving pressure-compensation. The simplest design for the pressure-compensating section comprises a single generally-rectangular open region, as shown in FIG. 2. The deformation of the top wall 5 and/or side walls 6 upon increased pressure in the large water supply passage 23 decreases the cross-sectional area of the pressure-compensating section 45.

Additionally, the flow section 28 further comprises at least one resistance element, i.e., an element that creates resistance to flow, which in turn creates a pressure drop. In the illustrated embodiment, the resistance element is located between the inlet section 26 and the

pressure-compensating section 45. Thus, the water pressure in the pressure-compensating section 45 is less than that in the water supply passage 23 of the hose 10, allowing the water pressure in the water supply passage to deform one or more walls of the pressure-compensating section. In the embodiment depicted in FIG. 2, the resistance element comprises an orifice 32 in a crosswall 33.

As discussed above, at least one wall, or a part of one wall, of the unibody emitter must be capable of deforming into all or part of the flow section 28. Preferably the emitters achieve an x-factor of 0.4 or less between 8 and 28 psi. More preferably the emitters achieve an x-factor of 0.35 or less, still more preferably 0.25 or less, and even more preferably 0.20 or less, between 8 and 28 psi. In a particularly preferred embodiment, the emitter achieves an x-factor 0.1 or less between 8 and 28 psi.

To achieve the required deformation, preferably the emitter is made of a single piece of material that is different from, and more deformable and elastic than, the material of the hose. A preferred emitter material comprises a thermoplastic elastomer, for example, a polyethylene-based thermoplastic elastomer, having properties similar to those of thermoset rubber, such as metallocene. The emitter could also be formed from another elastomeric material having similar flexibility properties.

Alternatively, the emitter material is the same as the hose material, but is structurally capable of deforming sufficiently into the flow section sufficiently to control flow within the emitter. For example, the thickness of the emitter material can be less than that of the hose material so that the emitter is more deformable than the hose. In another embodiment, the emitter is made from two or more materials that together form a single piece, which can be achieved, for example, by injection molding. Using multiple materials can be desirable for a number of reasons. For example, a more rigid material could be incorporated into the walls of the emitter near the inlet and outlet sections so that the walls do not deform into the inlet and outlet regions to completely block the flow of water into or out of the emitter. Additionally, if an expensive thermoplastic material is being use, a less deformable and less expensive material may be used in certain areas of the emitter where deformation is not required.

Depending on the elasticity of the material used for the emitter, the dimensions of the top and side walls of the emitter can be varied. For example, if the top wall is made of a highly elastic material, it can easily deform into the pressure-compensation region 45 regardless of the width of the emitter. However, if the top wall is made of a less elastic material, the width of the emitter can be increased so that the top wall can more easily deform into the flow section. Alternatively, the thickness of the top wall could be decreased, which also permits it to more easily deform into the flow section.

Additionally, different parts of the top, side and/or internal walls can be made of different materials and/or different thicknesses so that one or more walls deform into the flow section 28 to different degrees. A particularly preferred emitter design embodying this concept is depicted in FIGs. 3A to 3E. As shown in FIG. 3A, the flow section 28 contains a turbulent flow section 44 and a pressure-compensating section 45. The turbulent flow section 44 comprises a series of alternating baffles 47 that form a serpentine flow path. The baffles 47 form the resistance elements. An example of such a design is described, for example, in U.S. Provisional Patent Application Serial No. 60/045,764, the disclosure of which is incorporated herein by reference. Alternatively, the turbulent flow section 44 can comprise a labyrinth-type serpentine path, such as that described in U.S. Patent No. 4,880,167, the disclosure of which is incorporated herein by reference. The pressure-compensating section 45 follows the turbulent flow section 44 and is a generally rectangular open region. With this design, the turbulent (or serpentine) flow path creates flow resistance and a pressure drop in the water between the inlet section and the pressure-compensating section.

The top wall 18 of the pressure-compensating section 45, shown in FIG. 3D, is thinner than those of the inlet section 26, turbulent flow section 44, and outlet section 30, shown in FIGs. 3B, 3C and 3E, respectively. This design allows the water pressure in the main supply passage 23 of the hose 10 to compress the top wall 18 of the pressure-compensating section 45 toward the outer wall formed by the hose 10, thereby constricting water flow through that section. The absence of baffles 47 in the pressure-compensating section 45 facilitates the ability of the water pressure in the main supply passage 23 of the hose 10 to compress the top wall 18.

As shown in FIG. 4, another alternative design for the flow section comprises a nozzle section, i.e., a region that creates a nozzle effect by reducing the cross-sectional area of the water flow path and diverting the flow, thus guiding the water into a narrow channel, thus decreasing the pressure of the water flowing into the pressure-compensating section 45. In the depicted embodiment, the nozzle section 34 comprises two converging sidewalls 35, which are resistance elements. The converging sidewalls 35 increase the velocity of the water exiting the nozzle section 34, reducing the pressure of water entering the pressure-compensation region 45. Other designs for a nozzle section are disclosed in International Patent Application No. US 98/09254, filed May 6, 1998, the disclosure of which is incorporated herein by reference.

In another embodiment, two nozzles sections 34 (or any other sections containing a resistance element) and two inlet sections 26 are provided on opposite sides of the outlet section 30. As shown in FIG. 5, the flow regulating channel comprises two inlet sections 26,

two flow sections 28 and one outlet section 30. The two flow sections 28 each comprise a nozzle section 34 having two converging sidewalls 35.

An emitter 24 made of two different materials is depicted in FIG. 6. The flow section 28 comprises a turbulent flow section 44 and a pressure-compensating section 45. A first material 55 is used to form the top wall of the inlet section 26 and turbulent flow section 44. A second material 56 is used to form the top wall of the pressure-compensating section 45 and the outlet section 30. The second material 56 is more deformable than the first material 55 so that the top wall of the pressure-compensating section will deform into the flow section 28 to a greater extent than the top wall of the turbulent flow section 44. For example, the second material 56 can be made of a thermoplastic elastomer such as metallocene, and the first material 55 can be made of a low-density polyethylene.

When each emitter 24 is affixed to the interior of the hose, the inlet opening is inwardly directed and allows water from the water supply passage 23 of the hose to enter the flow section 28 in the emitter 24. After passing through the flow section 28, water exits through the outlet region 30. The outlet region 30 comprises an outlet opening in the hose 10 in fluid communication with the flow regulating channel 25, allowing water to exit the hose 10 at zero pressure. The pressure-compensating section in the flow section 28 ensures that the outlet drip flow rate from regions of the water supply passage 23 having relatively high water pressure will be substantially similar to the outlet drip flow rate from regions having lower water pressure.

In accordance with the invention, one or more of the indicated sections (inlet section, pressure-compensating section, outlet section or section containing the resistance element) can overlap in whole or in part with another of the sections. In other words, one section of the emitter may perform two functions. For example, the outlet section and the pressure-compensation section may occupy the same region of the emitter. Alternatively, the resistor element may be contained within the pressure-compensation section.

The emitters 24 described above are discrete emitters. Such emitters are typically situated within the hose 10 at discrete locations. Alternatively, the discrete emitters could be replaced with a continuous emitter strip, wherein the described flow sections 28 would be repeated at predetermined intervals, and the strip would be continuously affixed to the hose 10 along its length. Preferably the continuous emitter strip would have cross members to divide the strip into segments, each containing a flow section. Alternatively, the flow sections within the continuous emitter may not contain any discrete separations, i.e., have no walls between them, so that water in one flow section conceivably can flow into another flow section. However, if the material of the emitter is relatively expensive, discrete emitters is

preferred because they requires less material than a continuous emitter that extends along the entire length of the hose.

Hoses for use with the emitters of the invention can be constructed from any means known in the art. For example, an elongated thin plastic strip of film is folded longitudinally to form overlapping margins. Plastic ribs seal the overlapping margins, forming a water supply passage inside the folded plastic film. The ribs are preferably formed by extruding one or more molten plastic beads onto one margin of the film before it is folded.

An alternative method for making a hose involves a seamless, tubular hose, which can be formed through an extrusion process. The hose can be made of any suitable material, preferably polyethylene or a polyethylene blend. The product may be in tape form or in hard hose form.

The emitters can be made by any method known to those skilled in the art, such as injection, insert, or sequential molding. The emitters can then be adhered to the inside of the hose by any of several methods including, but not limited to, ultrasonic welding, thermal bonding, and bonding with adhesives. Alternatively, particularly in the case of a continuous emitter, the emitter can be extruded and formed by means of an embossing or imprinting tool. This technique is particularly useful if the hose is also being extruded. Thus, a continuous emitter could be extruded and formed, then inserted into a die center around which a hose is extruded. As the emitter and hose are extruded together, the emitter would be formed and adhered to the hose before it is cooled. Alternatively, the continuous emitter could be extruded and formed offline, and then fed through a hole in the die through which a hose is extruded. In a fourth embodiment, the continuous emitter could be fed and joined to a long continuous strip that is then folded to form a hose. Any other technique for making an emitter can also be used.

<u>Example</u>

A unibody emitter according to the invention was made, as shown in FIG. 7, depicted upside-down, i.e., with its top wall 5 on the bottom. The emitter 24 was made from metallocene sold under the trade name Engage™ (commercially available from DuPont/Dow). The pressure-compensating section 45 of the emitter was designed to overlap with the outlet section, i.e., the pressure-compensating section was positioned over the outlet opening in the hose. Thus, a groove 51 was provided in the pressure-compensating section 45 to prevent deformation of the top wall of the pressure-compensating section to completely restrict all flow out of the emitter 24. The emitter 24 was approximately 2⅛ inches long, 7/16 inch wide and had a height of 0.056 inch. The height of the flow section 28 within the emitter was approximately 0.018 inch. Within the pressure-compensating section

45 and the turbulent flow section 44 the top wall 5 had a thickness of approximately 0.038 inch. Within the inlet section 26, the top wall 5 had a thickness of approximately 0.057 inch. The width of the serpentine path within the turbulent flow section was 0.020 inch. The hose was made from polyethylene. The emitter 24 was found to have an average x-factor of 0.16 between 4 and 32 psi and an average x-factor of 0.07 between 8 and 28 psi.

The preceding description has been presented with reference to presently preferred embodiments of the invention. Workers skilled in the art and technology to which this invention pertains will appreciate that alterations and changes in the described structure may be practiced without meaningfully departing from the principal, spirit and scope of this invention. Accordingly, the foregoing description should not be read as pertaining only to the precise structures described and illustrated in the accompanying drawings, but rather should be read consistent with and as support to the following claims which are to have their fullest and fair scope.

CLAIMS:

1. A unibody pressure-compensating emitter for use in a drip irrigation hose, the emitter comprising a top wall and two side walls defining a flow section therebetween, wherein the flow section comprises an inlet section, an outlet section, a pressure-compensating section, and at least one resistance element, and wherein at least one of the top wall and side walls is capable of deforming into the pressure-compensating section with increased water pressure in the hose.

2. A unibody emitter according to claim 1 having an x-factor of about 0.40 or less between 8 and 28 psi.

3. A unibody emitter according to claim 1 having an x-factor of about 0.35 or less between 8 and 28 psi.

4. A unibody emitter according to claim 1 having an x-factor of 0.30 or less between 8 and 28 psi.

5. A unibody emitter according to claim 1 having an x-factor of about 0.20 or less between 8 and 28 psi.

6. A unibody emitter according to claim 1 having an x-factor of about 0.10 or less between 8 and 28 psi.

7. A unibody emitter according to claim 1, wherein the pressure-compensating section is between the inlet and outlet sections.

8. A unibody emitter according to claim 7, wherein the at least one resistance element is between the inlet section and pressure-compensating section.

9. A unibody emitter according to claim 1 made of an elastomeric or thermoplastic material.

10. A unibody emitter according to claim 1 made of a single material.

11. A unibody emitter according to claim 1 made of two or more different materials.

12. A unibody emitter according to claim 1, wherein the pressure-compensating section comprises a generally rectangular open region.

13. A unibody emitter according to claim 7, comprising a turbulent flow section between the inlet section and pressure-compensating section.

14. A unibody emitter according to claim 13 having an x-factor of about 0.35 or less between 8 and 28 psi.

15. A unibody emitter according to claim 1, wherein the emitter is a discrete emitter.

16. A unibody emitter according to claim 1, wherein the emitter is a continuous emitter.

17. A unibody emitter according to claim 13, wherein the emitter is a discrete emitter.

18. A drip irrigation hose containing at least one unibody emitter according to claim 1.

19. A drip irrigation hose containing at least one discrete unibody emitter according to claim 1.

20. A drip irrigation hose containing at least one unibody emitter according to claim 13.

21. A drip irrigation hose containing at least one discrete unibody emitter according to claim 13.

FIG. 1

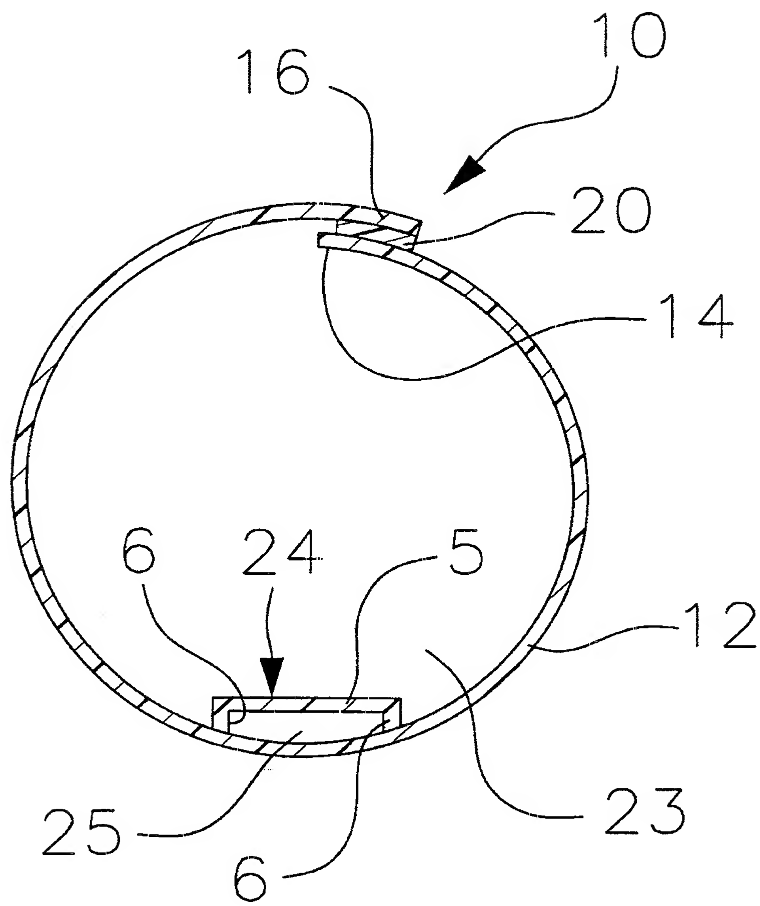


FIG.2

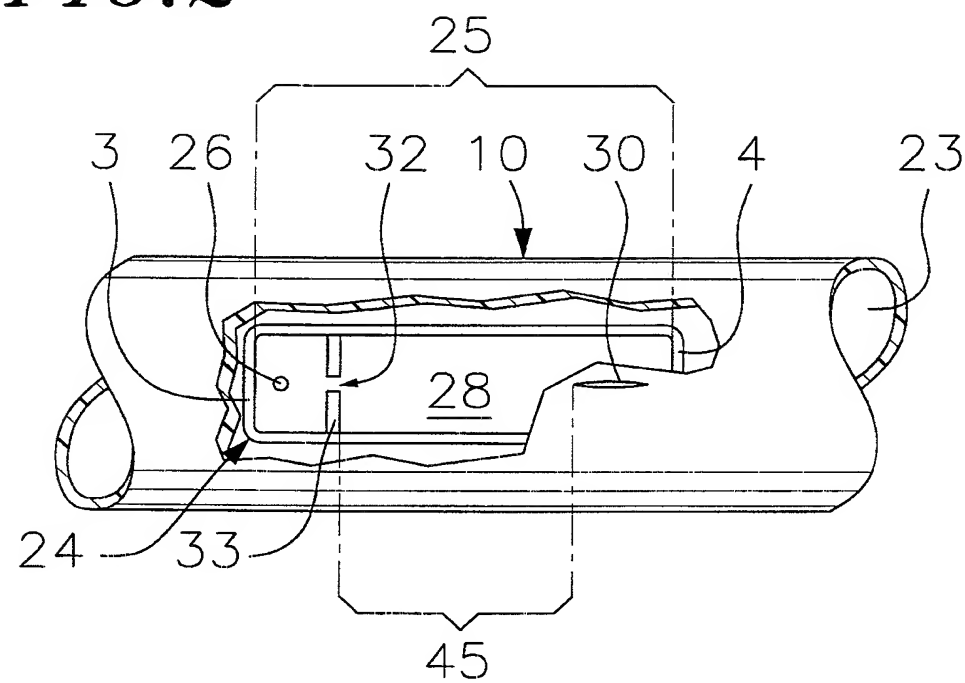


FIG.4

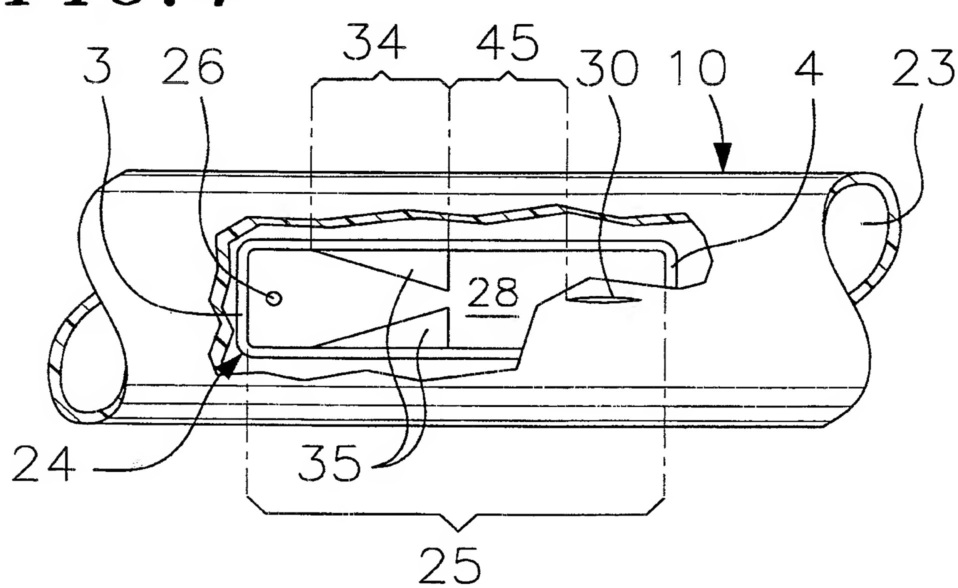


FIG. 3A

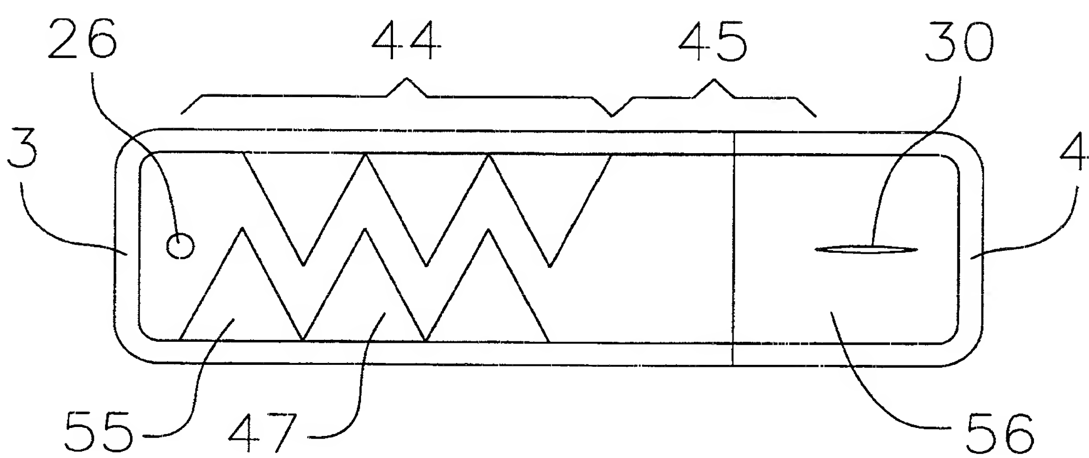


FIG.3B

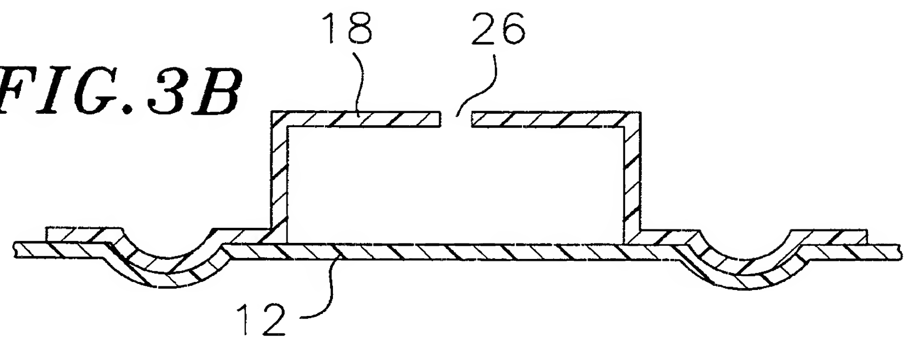


FIG.3C

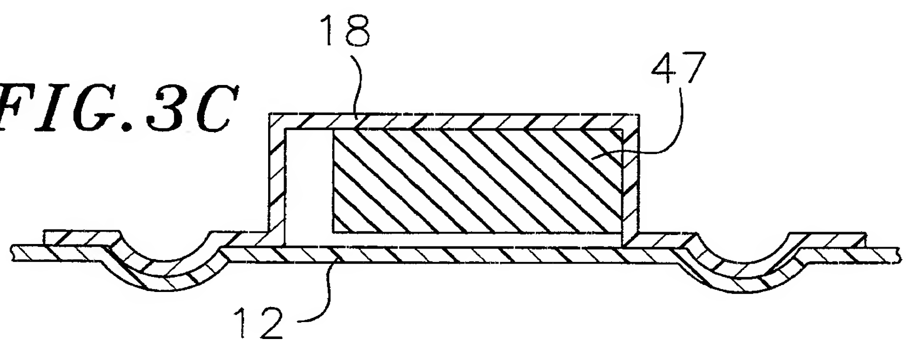


FIG.3D

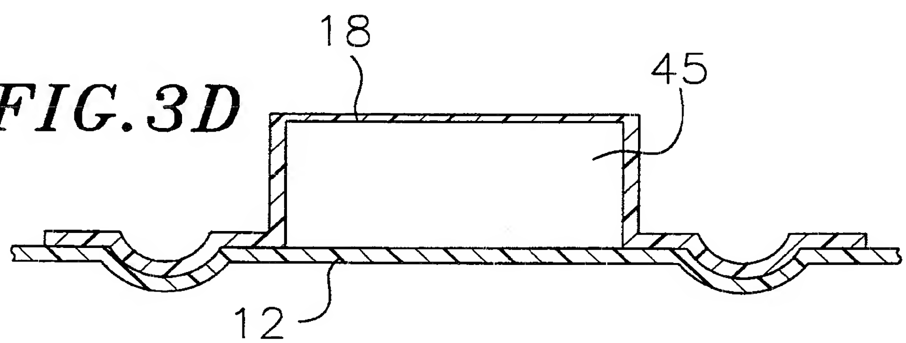


FIG.3E

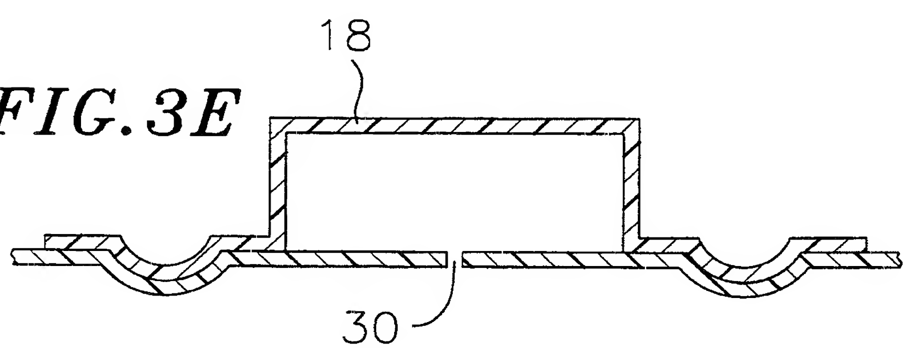


FIG.5

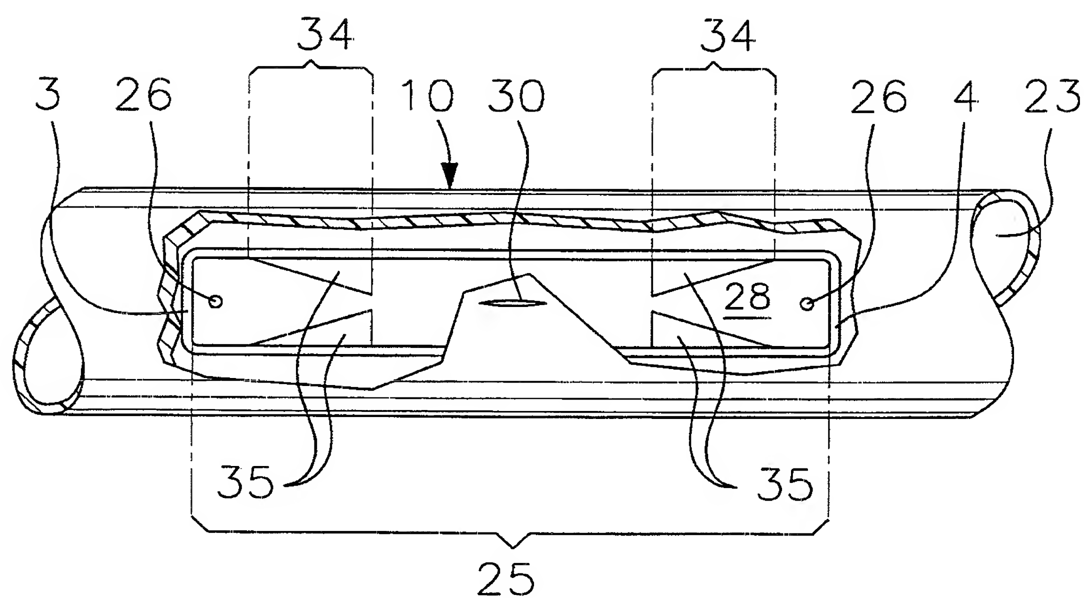
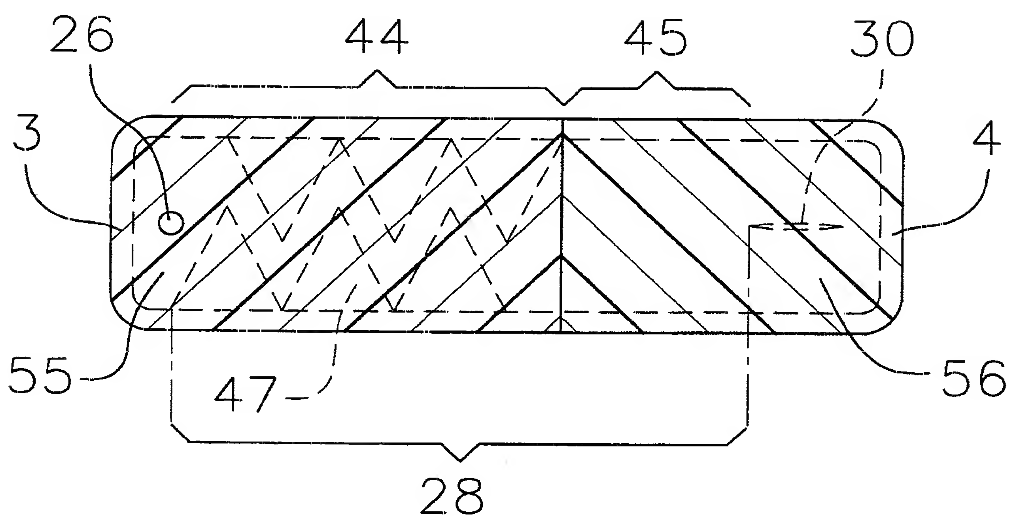


FIG. 6



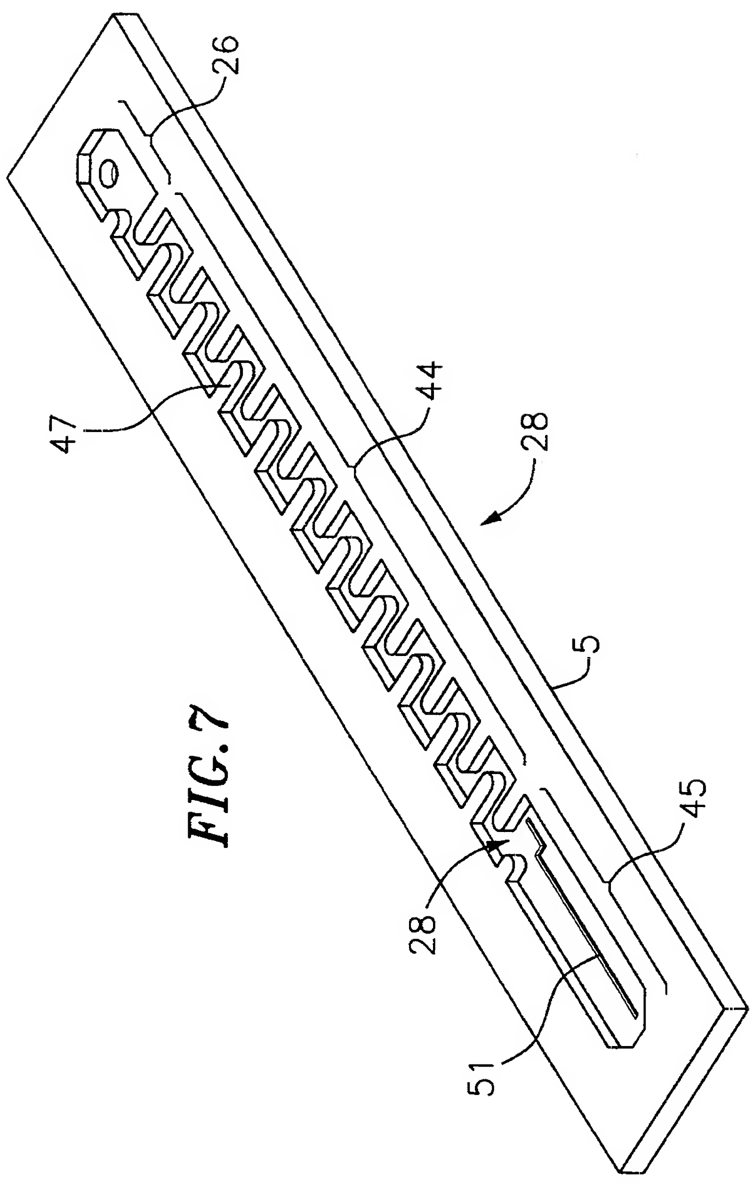


FIG. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US98/14245

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :B05B 15/00
US CL : 239/542, 533.1, 562
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 239/533.1, 533.13, 542, 548, 553, 553.3, 562, 568

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

APS

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X ---- Y	US 4,254,791 A (BRON) 10 March 1981, see entire document.	1, 7-13, 15 and 17-21 ---- 16
X ---- Y	US 5,203,503 A (COHEN) 20 April 1993, see entire document.	1, 7-13 and 15-21 ---- 2-6 and 14
X ---- Y	US 5,330,107 A (KARATHANOS) 19 July 1994, see entire document.	1-10, 12-15 and 17-21 ---- 11 and 16

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
02 SEPTEMBER 1998	16 OCT 1998

Name and mailing address of the ISA/US	Authorized officer
Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231	J. Hurley for ANDRES KASHNIKOW
Facsimile No. (703) 305-3230	Telephone No. (703) 308-1113

Form PCT/ISA/210 (second sheet)(July 1992)★

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US98/14245

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X ---- Y	US 5,333,793 A (DeFRANK) 02 August 1994, see entire document.	1, 7-9, 11-13, 16, 18 and 20 -------- 2-6, 10, 14-15, 17, 19 and 21